AN INVESTIGATION OF FUNGICIDES FOR THE CONTROL OF *RHIZOPUS NIGRICANS* CAUSING SOFT ROT IN SWEETPOTATOES

by

GAYTHER LYNN PLUMMER

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INTRODUCTION

Sweetpotatoes, the second most important vegetable crop in the United States, are subject to several diseases which have been known to destroy as much as one-fourth the annual harvest. The soft rot disease causes a loss of more than 10 percent of the sweetpotatoes that are produced each year. To prevent diseases in other fruits and vegetables, chemical materials are frequently employed to reduce the losses. A fungicide that will prevent the soft rot disease in sweetpotatoes would be an asset to all those handling the roots.

Although the quality and yielding ability of sweetpotatoes have, in past years, been improved, the numbers of bushels produced has not increased proportionally to the increase in the consumers market or the population of this country (Fig. 61). The population of the United States has increased about 3.6 times since 1870 yet the production of sweetpotatoes, reaching its peak around 1935, was 2.6 times greater than the sweetpotatoes produced around 1870. Since 1935 sweetpotato production has fallen rapidly and in 1948 for nearly 145 million people only about 49 million bushels were produced compared to 29 million bushels for 45 million people before 1885. Table 1 indicates the number of farms reporting sweetpotatoes by acres harvested in 1939 for the United States.

The Disease and Recommendations for Control

Soft rot, as the name implies, causes a soft wet rot of affected sweetpotatoes. The infection usually spreads rapidly thruout the entire root but sometimes only a portion of the root decays. Following the rapid invasion, the decayed area dries down to a shapeless mummy. The color of rotting

sweetpotatoes is somewhat darker than normal. An odor results which is characteristic of this disease. Whenever soft rot is present in a sweetpotato storage house, it can readily be detected by this pungent odor.

Soft rot infections occur only thru wounds. No method is known as to how to prevent infections of sweetpotatoes in the field excepting, to avoid injuring the roots during cultivation. Prevention of soft rot after the roots are harvested consists of:

1. Avoiding cutting, bruising or otherwise injuring the roots during harvest.

2. Placing sweetpotatoes in a curing environment immediately after they are harvested. The roots should be cured 10-14 days at 85 to 90 percent humidity and 85° F. Such environment causes rapid healing of wounds.

3. Allowing the roots to remain undisturbed so as not to again injure them until they are marketed.

4. Avoid chilling the roots. Sweetpotatoes should be stored at no lower than 50° F.

5. Preventing mice and rats in the storage house as these rodents not only bite into many roots but puncture the skin of the roots with their claws.

Purpose

The purpose of this investigation is to find a fungicide that would inhibit the infection of the sweetpotato roots by the soft rot organism, *Rhizopus nigricans*, Ehrenb. Inhibition is sought at a concentration of the fungicide that is nontoxic and nonirritating to human beings. The materials used were either soluble or suspendable in water. This investigation is an evaluation of forty-seven fungicides using wounded sweetpotato roots in dip treatments.

REVIEW OF LITERATURE

Lauritzen and Harter (14) point out that Rhizopus tritici, Saito, and Rhizopus nigricans, Ehrenb., are the two species chiefly responsible for the decay of sweetpotatoes, known as soft rot. The former is responsible for decay at the higher and the latter at the lower temperatures, while the two overlap between 20° and 30° C. Although other species, R. arrhizus, Fischer, R. oryzae, Went., R. reflexus, Bainier, and R. artocarpi, Racib., are capable of causing soft rot, they do not seem to do so under the storage conditions most generally used.

Rhizopus nigricans, according to Harter and Weimer (6) is a fungus that is present almost everywhere. It attacks a great variety of vegetable materials, including fruits, and bread. It is most prevalent as a saprophyte but is also a weak parasite, being able to attack such living tissues as strawberries, various other fruits, sweetpotatoes, etc. It does not attack leaves and stems, neither does it attack the fibrous roots of the plant.

The fungus produces conidia (asexual spores) and zygospores (sexual spores). The conidia are borne in sporangia that are produced directly from the mycelium and also from the germinating zygospores. The conidia are distributed by air currents, are omnipresent, and are the source of infection causing the soft rot disease.

The search thru literature, trying to find chemicals either organic or inorganic, that will control this fungus, at concentrations tolerable for human consumption, has almost been in vain. Only on a few occasions is Rhizopus ever mentioned in connection with fungicides.

Tanner (21) writes that Rhizopus nigricans, the black bread mold, has been . . . controlled in the baking industry for quite some time by the use of sodium and calcium propionate. The former is sold under the commercial name, Mycoban.

In 1941, Daines (2) reported, "Borax Does It." Results of his work are recorded in Table 2.

Continuing, Daines writes, "so successful was borax in preventing soft rot that markets that had been closed to certain sweetpotatoes began accepting them and sometimes even at a premium." The same author later reported (3), "In a prestorage dip experiment conducted in New Jersey it was found that potatoes dipped in sodium borate shriveled excessively. Of the other materials tested tetrachloro para benzoquinone, tumaric acid, and bordeaux mixture, none proved to be better, from the standpoint of shrinkage or disease control, than the untreated check."

Also using Borax, Parris (17) reported injury using 2.5 or 2.0 percent instant dip. He added

> Injury from borax was unexpected and is unfortunate, . . . and the dip (2.5 or 2.0 percent) is unsurpassed as a fungicide for the control of R. nigricans. Even though a heavy spore suspension be incorporated with the borax solution, sweetpotatoes dipped therein rotted but little, whereas, roots dipped in a comparable spore suspension without borax are rotted, immediately and appreciably. Borax treated roots have been retained for over a month; they did not have a favorable appearance at the end of the test, but they did not rot.

Parris (17) also mentioned that the United States Rubber Company's #604 (Phygon) will also control R. nigricans and soft rot, "but it is not the equal of Borax." He also mentioned that waxes themselves have no fungicidal action against the soft rot fungus under the experimental conditions of the tests.

Further evidence of the lack of work that has been done on this subject comes from correspondence with twenty-five different chemical companies in the United States and Canada. Not one company offered chemicals or other materials that were known to inhibit or control the growth of Rhizopus nigricans.

MATERIALS AND METHODS

Preparation and Collection of Materials

The sweetpotatoes used to carry out the investigation were chiefly of the variety Orlis.

Two gallon metal soil-buckets were used to contain the pieces of sweetpotatoes thruout all storage house investigations.

A commercial storage house was used in the early investigations and later a large army-surplus food cooling box was used as an infection chamber and called an experimental storage house.

A letter of inquiry was sent to 26 chemical companies asking for experimental samples of any material that was nontoxic and nonirritating to human beings, and that this material be either soluble or suspendable in water.

Only one company, R. J. Vanderbilt Company, replied with assurance that their fungicides were nontoxic and nonirritating to human beings.

Therefore, numerous fungicides were accepted and tested upon the recommendation from the producers that they were nontoxic and nonirritating at some high dilution concentration. One fungicide, the antibiotic Acti-dione, was labeled "Poison" and was not recommended for human consumption at any concentration.

Altogether, 47 different materials contributed by twelve different chemical companies were received. Thirteen chemical companies had nothing to offer.

Laboratory Investigations

A laboratory evaluation of the fungicides was made in order to determine a concentration at which the soft rot fungus itself is inhibited and to find a concentration at which infection of sweetpotatoes is prevented.

Petri dishes (150 mm in diameter), ordinary potato dextrose agar (PDA), 3/4" paper discs cut from filter paper, sweetpotato root plugs 3/4" in diameter and about 3/16" thick and the various fungicides were the basic materials used in the laboratory investigation.

A solution or suspension of each fungicide was made with distilled water at these concentrations: low, 0.1 percent; medium 1 percent; and high, 10 percent.

In preparing the PDA sishes, sterile water was added to a pure test tube culture of Rhizopus nigricans and siphoned into a sterile pipette. To a tube of sterile melted (45°C.) PDA a few drops of the spore suspension from the pipette was added; this was then poured into the sterile petri dish. Duplicated petri dishes of inoculated PDA were marked off into thirds and were thus ready for the preliminary test of the three concentrations of each fungicide.

Starting with the low concentration, a sweetpotato plug and a filter paper disc were placed side by side in the lower third of each petri dish. This procedure was repeated for the medium concentration in the second third of the petri dish and also for the high concentration in the remaining third. Duplicated petri dishes of inoculated PDA were thus prepared, each dish having three concentrations of one fungicide, each concentration represented by a sweetpotato plug and a paper disc. The petri dishes were then incubated for 36 hours at 25° C.

In order to obtain a permanent impression that could be retained for further comparisons, a photograph of the better of the duplicated incubated plates was made for all but two fungicides tested. These photographs (PLATES I, II, III) were made after 36 hours incubation because the density of the mycelial growth at that time was not too great and at the same time the initial effectiveness of the fungicide could be recognized (compare with Figs. 57-60, 16 hr.-incubated-dishes). A negative print of each plate was made by exposing thru the plate directly on contact printing paper. These negatives were then mounted, reduced during copying, and finally a positive print was obtained.

In some cases, where the fungicide was exceedingly active at the high concentration, lower concentrations were tested and recorded. On a few other occasions as found in Pl. III, extremely high concentrations were recorded only for comparisons.

Concentrations showing good inhibition, good protection, and feasible use were chosen for dip testing sweetpotatoes under experimental storage house conditions. Each fungicide was tested in at least one concentration.

Since the value of the preliminary laboratory evaluation has not been proved, this procedure was again checked by taking samples of each of the fungicides from the actual dip concentrations used to treat the pieces of roots. These were brought back into the laboratory for a check against original analysis of the effect of the various concentrations. Exactly the same laboratory procedure as outlined previously was followed. No photographs were made of this check unless all indications led to errors in the preliminary investigations. In nearly every case the results of this check were either identical or comparable to the results that had been obtained in the

preliminary evaluation and recorded on the photographs. Whenever this was not true, the entire evaluation was made again. Any deviation from the normal expectations are recorded in the section on OBSERVATIONS AND RESULTS.

Experimental Storage House Investigation

This part of the investigation was begun during the fall of 1948. During the early trials, the commercial storage house (CSH) containing the harvested sweetpotato crop was used to provide natural infection. Various ways of getting 100 percent decay were tried but the percentage of rot in the untreated tests varied from 15 percent to 100 percent and only on one occasion did it ever get above 93 percent decay. It was important that 100 percent decay be obtained, therefore, other means of achieving this and at the same time assimilating the conditions to those of the storage house were sought.

This prompted the use of an infection chamber as an experimental storage house (ESH). By thermostatically controlling the temperature and by crudely dehydrating with calcium chloride, a range of temperatures and humidities permitting 100 percent infection was obtained. This range was found to be within the same limits for temperature and relative humidity that has been reported by other workers.

A temperature between 60° and 65° F. was constantly maintained. This range of variation is between the recommended storage house temperatures of 55° F. and the optimum temperature best suited for the growth of *Rhizopus nigricans*, 73° to 75° F.

The relative humidity of the ESH was about 95 percent if it were left undisturbed for more than 24 hours. However, if the entire volume of air

were changed at least once each day by opening the door and by turning on a large blower type fan within the box, the relative humidity varied from about 85 to 92 percent nearly all the time.

At these temperatures and these humidities the formation of wound cork is delayed about four or five days.

Application of Fungicides

Beginning with the investigations under the ESH conditions and in accordance with the indication from the preliminary laboratory survey, suitable concentrations of each fungicide were prepared for treating cut roots.

A treating mixture of each fungicide was prepared on a percentage weight or volume basis and on several occasions, grams per liter.

The use of detergents was necessary for a few fungicides. Whenever this was encountered, Dreft, a commercial washing compound, or else Areskap 100, a preparation from Monsanto Chemical Company was used.

The sweetpotatoes were cut into pieces, the smaller roots were halved and the larger roots quartered. The roots were cut lengthwise in order that the largest available wounded surface might be exposed to the inoculum. The pieces were then divided into lots of fifty each and put into the clean soil buckets. Each lot of fifty pieces was individually dumped into the concentration of the fungicide. After one to three minutes in this dip treatment the fungicide was drained off and the soil buckets were placed in the ESH. A duplicate for each treatment was made. Several times the same concentration of one fungicide was used over again at a different set of trials.

As soon as all the treated roots in the buckets were in the ESH, the inoculum was disseminated by putting into a cotton bag some shriveled pieces

of sweetpotato roots that were covered with sporulating mycelia solely for the purpose of obtaining inoculum. These infected pieces had never before been treated with a fungicide. By shaking vigorously, a cloud of Rhizopus spores, along with the spores of a secondary fungus, Penicillium, was soon stirred up. These spores were then circulated by means of an electric fan within the ESH for several hours. The treated pieces of sweetpotato roots were left undisturbed in this environment for at least two weeks. A period of four weeks was originally used but the difference in the percentage decay was an average of less than 2 percent. Following this two-week period, the pieces of sweetpotato roots in each bucket were counted and the number of decayed pieces recorded as percent decay (Table 3).

Untreated Checks

For every series of tests made, an untreated check was also set up. Only at three different times did the untreated checks yield less than 100 percent decay. Twice during the investigations, because of mechanical failure of the refrigerating unit the temperature got above 83° F. This caused less than 15 percent rot in the untreated checks because optimum healing conditions were present. On another occasion, probably because of high humidity and warm temperatures before the untreated check was put into the infection chamber, the decay was 95 percent. During all other tests, there was 100 percent decay in the untreated checks.

Soft Rot and Chemical Injury

Soft rot was distinguished from chemical injury by two principal methods: the presence of the characteristic pungent odor that accompanies soft rot decay, and also by the dark shiny breakdown of the tissue in the

presence of high concentrations of the respective fungicides. Usually in the presence of chemical injury, no fungi were present.

Collection of Data

Technical data on the fungicides, in most cases, was supplied by the chemical companies. These data precede the OBSERVATIONS on each fungicide and have been used freely, without references.

Data on the preliminary survey made in the laboratory are recorded in the explanations of Plates I, II, III, opposite the respective plates.

The data collected from the results in the ESH are reported in the following section and the amount of decay is recorded in Table 3.

OBSERVATIONS AND RESULTS

The laboratory evaluation of each fungicide was made at 72 hours from the plates that were used for photographing. Each plate was kept for at least one week; additional data were taken if necessary. Wherever *Rhizopus* was present on the plates and, in general, where there was no inhibition, seldom were other fungi obviously present. In the plates that did show pronounced inhibition of *Rhizopus*, various species of *Penicillium* and *Aspergillus niger* nearly always infected the decaying sweetpotato plug. If the plug did not decay, the other fungi did not so readily appear.

Accompanying *Rhizopus nigricans* in all storage house tests was an association of *Penicillium* spp. These organisms developed within 10 days but seldom were they noticeable before 7 days. In several cases this fungus was present with the absence of *Rhizopus*, in very high concentrations of the fungicide. On other instances, the fungicide inhibited both *Rhizopus* and *Penicillium*. Wherever the latter was present a dark shallow surface rot usually accompanied.

The following information includes technical data, observations and results obtained from this investigation of the 47 fungicides.

Dowcide F

Active Ingredient. 80 percent 2,3,4,6 - tetrachlorophenol, sodium salt.

Producer. The Dow Chemical Company.

Chemical and Physical Data. A brown flaky, volatile powder that is soluble in water. It is hazardous from the standpoint of possible dermatitis and systemic intoxication from dust dispersals in the atmosphere. Oral toxicity is somewhat high, the largest dose permitting survival of all the animals fed, being 0.1 gram per kilogram body weight.

Fungicidal Efficiency. Chlorination of phenol increases its fungicidal effectiveness from 2 to 100 times (Horsfall, 1945, p. 151). This material is among the most toxic of many fungicides. Specific data were not available.

Laboratory Observations, PLATE I, Fig. 1. Definite reduced mycelial growth over the entire plate. At 36 hours plugs at 0.1 percent and 1 percent were infected. After 72 hours the plug at 10 percent was not decayed but the fungus was creeping over the entire plate so that within 5 days the 10 percent plug was decayed and the mycelium covered the entire plate without restriction, except for sporulation which was and remained inhibited. Dowcide F was fungicidal at 3 percent concentration and above; fungistatic below 3 percent.

ESH Observations. Dowcide F inhibited the superficial growth of R. nigricans and other fungi completely at all concentrations above 0.5 percent. At concentrations of 2.5 percent and 5 percent, chemical injury was outstanding. Protection was good; for 6 tests involving 300 sweetpotatoes at 1 percent concentration, there was 1.3 percent decay on one occasion. With the same concentration at another incident there was 3 percent decay.

Dowcide B

Active Ingredient. Sodium salt of 2,4,5-trichlorophenol, 85 percent.

Producer. The Dow Chemical Company.

Chemical and Physical Data. A red-brown flaky material, soluble in water and somewhat volatile. This material is toxic when swallowed but systemic poisoning, even from dust, is not a serious health hazard.

Fungicidal Efficiency. Will compare with other chlorinated phenols, see Dowcide F.

Laboratory Observations, Plate I, Fig. 20. Very pronounced inhibition over the entire plate. Due to the volatility of Dowcide B the concentration gradually decreased and the growth of the fungus gradually increased so that within 72 hours the plugs at the low concentration as well as the medium concentration were decayed. The plug at the high concentration did not decay at any time. The entire plate was affected by the high concentration (10 percent). Check plates showed no mycelial growth at concentrations of 4 percent or better. At 1 and 2 percents, mycelial growth is delayed for about 36 hours.

ESH Observations. Increased concentrations of Dowcide B decreased the amount of soft rot. At 5 percent concentration there was no decay but there was chemical injury of the pieces of sweetpotato around the cut surfaces.

SCD - 765

Active Ingredient. 14 percent 2,4,5-trichlorophenol.

Producer. The Dow Chemical Company.

Chemical and Physical Data. A dark brownish-red liquid. It is soluble in water in all concentrations. When diluted in water for testing purposes at the rate of 1/100, 1/500, and 1/1000, this Dowcide is "very low in human toxicity and at the dilutions recommended, we felt that you can use this without hazard to humans."

Fungicidal Efficiency. See Dowcides F and B.

Laboratory Observations, Plate II, Fig. 27. The mycelia grew abundantly and luxuriantly in the maximum concentration recommended for human tolerance, 0.1 percent. There was complete mycelial inhibition at 10 percent and the plug was protected for about 48 hours, at which time the plug began to break down because of chemical injury. The mycelium did not grow beyond the area established at 36 hours. Note the reduced sporulation as affected by the high concentration. All plugs were decayed by 72 hours.

ESH Observations. In the preparation of the tests a skin irritation was encountered at 10 percent. According to technical data received from the company, this should have been expected; there is no danger of poisoning through the skin. At the maximum concentration recommended for human tolerance, 0.1 percent SCD allowed 36 percent rot on one occasion when the refrigerating unit was not functioning properly and the temperature increased to 85° F. On another occasion 95 percent rot was obtained using 0.1 percent of SCD.

Seedox 50 W

Active Ingredient. 2,4,5 trichlorophenyl acetate.

Producer. Sindar Corporation, distributed thru R. J. Prentiss and Co.

Chemical and Physical Data. A 30 percent blue wettable dust that is insoluble in water. It is definitely volatile. Six month studies showed no change in the growth curves of test animals and examination of the internal organs when the animals were slaughtered showed no pathological changes.

Fungicidal Efficiency. This material has been used for treatment of gladiola corms with successful results.

Laboratory Observations, Plate III, Fig. 50. No mycelial inhibition at any concentration. All the plugs decayed.

ESH Observation. Tested with two concentrations 1 percent and 5 percent, Seedox 50 W allowed 88 percent and 100 percent decay respectively.

G - 4 - 40

Active Ingredient. 40 percent sodium salt of 2,2' dihydroxy 5-5' dichloro diphenyl methane.

Producer. Sindar Corporation.

Chemical and Physical Data. This is a deep red-brown solution with water. Studies on dogs indicate there is MLD_{50} of 2.0 grams per kilogram of body weight.

Fungicidal Efficiency. Used extensively by the armed forces during World War II for mildew proofing fabrics (Frear (5), p. 263).

Laboratory Observations, Plate III, Figs. 45 and 46. Mycelial growth was vigorous and abundant in Fig. 45. There was slight inhibition at a concentration of 10 percent. The fungus growth was stimulated in higher concentrations. Fig. 46 shows extremely high concentrations; the stimulated growth of the fungus and the maximum lethal concentration.

ESH Observations. In these tests that were considered valid, there was more than 90 percent decay in all concentrations tested.

P. C. P.

Active Ingredient. Pentachlorophenol mono sulfide.

Producer. B. F. Goodrich Chemical Company.

Chemical and Physical Data. This is a white-gray powder that is not soluble in water and is to be used, if necessary, with VL - 600 at not more than 0.1 percent concentrations.

Fungicidal Efficiency. Known to prevent rot of cellulose in burlap, particularly textile, rope and various wood products (Frear (5), p. 262).

Laboratory Observations, Plate II, Fig. 39. There was reduced mycelial growth in the high and low concentrations. Also, there was good inhibition in both the 10 percent and 0.1 percent areas, especially around the cellulose paper disc. Whether or not this has any significance is not known. All the plugs were decayed at 36 hours.

ESH Observations. P. C. P. was not at all effective in the experimental storage tests. At the recommended use concentration there was 94 percent decay.

Dowcide A

Active Ingredient. Sodium salt of ortho-phenyl phenol.

Producer. The Dow Chemical Company.

Chemical and Physical Data. A gray flaky material, soluble in water and somewhat volatile. This material presents no serious health hazards but may cause some local irritation in the upper respiratory passages. There is no danger of systemic poisoning; dermatitis is not a serious problem.

Fungicidal Efficiency. Effective in protecting citrus fruits from attacks, used as impregnated paper wrappings. Has been used against *Sclerotinia laxa*, *Coryneum beijerinckii* in apricots and almonds (Frear (5), p.262).

Laboratory Observations, Plate I, Fig. 19, and Plate III, Fig. 59. Pronounced inhibition at the high concentration, this lasted for over 2 weeks. Plugs at 0.1 percent and 1 percent concentration decayed within 36 hours. The plug at 10 percent concentration remained uninfected for over 2 weeks.

ESH Observations. As the concentration of Dowcide A increased the amount of soft rot decreased until there was complete protection, with some chemical injury at 5 percent concentration.

Puratize - 177

Active Ingredient. 100 percent phenyl ammonium cadmium dilactate.

Producer. Gallowhur Chemical Corporation.

Chemical and Physical Data. A white "powder possessing no odor or irritating properties, and marked stability. It is water soluble and . . . nontoxic to humans at recommended concentrations." Recommended dilutions: 1 pound per 12 gallons water and 1 pound per 48 gallons water.

Fungicidal Efficiency. "Class A fungicide against common laboratory organisms. It exhibits the unique ability to control certain fruit fungi. . ."

Laboratory Observations. Plate I, Fig. 13, Plate III, Fig. 57. Mycelial growth reduced over the entire plate. Good inhibition especially in the high concentration. All plugs decayed after 48 hours.

ESH Observations. There is no correlation between the amount of decay and the concentration of the fungicide. At concentrations of 1 percent and 5 percent there was 76 percent and 23 percent decay, respectively.

Sinox W

Active Ingredient. 13 percent ammonium salt of dinitro secondary butyl phenol.

Producer. Standard Agricultural Chemicals, Inc.

Chemical and Physical Data. Not supplied by the producer.

Fungicidal Efficiency. Not supplied by the producer.

Laboratory Observations, Plate I, Fig. 5. Reduced mycelial growth over the entire plate; very little sporulation. Distinct areas of inhibition in all concentrations. Plug at 0.1 percent concentration decayed within 42 hours; 1 percent plug decayed at 65 hours and the 10 percent plug decayed after 5 days. The latter decayed because of chemical injury.

ESH Observations. There was no growth of any fungus at 5 percent or at 1 percent concentrations and very little growth of *R. nigricans* at 0.5 percent concentration. Sinox W was more effective than most other materials tested. There was an average of 16½ percent decay involving 200 roots at 1 percent concentration. This was consistently lower than any other material tested.

Sinox

Active Ingredient. Sodium salt of 4,6 dinitro ortho cresol (a 30 percent concentration containing no penetrants).

Producer. Standard Agricultural Chemicals, Inc.

Chemical and Physical Data. The solution is a dark oily material having a heavy yellow precipitate. This yellow dye is called Victoria yellow and appeared in 1909 under the name Basilite. Reappeared in 1912 as a wood preservative in Germany known as Antinnonin (Horsfall (9), p. 150). Toxicological data were not available.

Fungicidal Efficiency. Has been suggested for eradicating *Venturia inaequalis* from old apple leaves on the ground. Also is a selective weed killer.

Laboratory Observations, Plate I, Fig. 4. Reduced mycelial growth and also reduced sporulation over the entire plate. Well defined areas of inhibition in the medium and high concentrations. Plugs at 0.1 percent and at 1 percent decayed within 36 hours. Plug at 10 percent did not decay after 5 days; neither was there evidence of chemical injury until after 10 days.

ESH Observations. Sinox allowed 100 percent decay in all concentrations tested. There was no superficial growth of any fungus at 5 percent concentration but there was definite chemical injury in all the pieces of sweetpotatoes. Neither was there growth of any fungus at 1 percent or 0.5 percent.

Elgetol

Active Ingredient. Sodium salt of 4,6 dinitro ortho cresol.

Producer. Standard Agricultural Chemicals, Inc.

Chemical and Physical Data. The solution is a dark oily material with a heavy yellow precipitate. Data on toxicity were not supplied by the producer.

Fungicidal Efficiency. Not supplied by the producer.

Laboratory Observations, Plate I, Fig. 6. Reduced mycelial growth over the entire plate. Sporulation was only slightly reduced. Well defined areas of inhibition were present in the high concentration (10 percent) especially around the paper disc. Sweetpotato plugs decayed at 36 hours at all concentrations.

ESH Observations. *Rhizopus nigricans* grew abundantly over the surface of the cut sweetpotato roots. Elgetol was not effective; it permitted 100 percent decay at 1 percent concentration.

Bioquin

Active Ingredient. 8-quinolinol.

Producer. Monsanto Chemical Company.

Chemical and Physical Data. Light brown powder that must be used with a detergent (Areskap 100) before it suspends readily in water. Recommendations were suggested not to exceed 1 pound per 100 gallons water (0.125 percent). At such use-dilutions "a relatively low order of toxicity to warm blooded animals" is encountered.

Fungicidal Efficiency. Data not supplied by the producer.

Laboratory Observations, Plate I, Fig. 7. The effectiveness of Bioquin seems to be in the suppression of the ability of the fungus to sporulate rather than the suppression of its infective ability. All plugs decayed within 36 hours during the first set of trials. The concentrations were increased and tested on a wider range (see Explanation of Plate I, Fig. 7). These were much higher than recommended concentrations but the areas of inhibition were equally as much increased.

ESH Observations. Used with a detergent, Areskap 100, Bioquin gave variable results. In all cases where tests were considered valid, there was greater than 50 percent decay, even at very high concentrations of 1 percent. During one set of tests, the temperature became too high and reduced the decay to below 15 percent.

Bioquin I

Active Ingredient. Copper-8-quinolinolate.

Producer. Monsanto Chemical Company.

Chemical and Physical Data. A green powder that suspends easily in water with Areskap 100. Use-dilutions, 1 pound per 100 gallons water (0.125 percent), possess "a relatively low order of toxicity to warm blooded animals."

Fungicidal Efficiency. Not supplied by the producer.

Laboratory Observations, Plate I, Fig. 8, and Plate III, Fig. 41. This fungicide seldom produced consistent results when tested on different occasions using the same concentrations. In all cases, however, there were no decayed sweetpotato plugs at any concentration tested.

ESH Observations. In all concentrations tested Bioquin I gave variable results in the ESH also. At no single concentration were results so significant to substantiate a valid conclusion. The results obtained in the laboratory indicated good possibilities for storage tests but these did not materialize.

Bioquin 100

Active Ingredient. Zinc-8-quinolinolate.

Producer. Monsanto Chemical Company.

Chemical and Physical Data. A light gray-brown powder insoluble in water and must be used with a wetting agent. Use-dilutions of 1 pound per 100 gallons (0.125 percent) water possess "a relatively low order of toxicity to warm blooded animals."

Fungicidal Efficiency. Not supplied by the producer.

Laboratory Observations, Plate I, Fig. 11-12. In low concentrations, 0.1 percent to 2.2 percent, very little inhibition resulted. Sporulation was reduced in Fig. 12 and all the plugs are decayed. Note reduced mycelial growth in Fig. 12. Fig. 11 shows reduced mycelial growth also, over the entire plate, however, and inhibition in the low concentration around the paper disc. The plug decayed after 84 hours in the low concentration but the others remained uninfected.

ESH Observations. Where tests were considered valid, the amount of decay was 60 percent or greater at all concentrations tested.

Oxyquinoline Base

Active Ingredient. 8-hydroxyquinoline.

Producer. Merck and Company, Inc.

Chemical and Physical Data. This material is a white crystalline powder that is soluble in water.

Fungicidal Efficiency. Not known.

Laboratory Observations, no Photographs Were Made. In the petri dish cultures, there was an abundance of mycelial growth. All the plugs were infected in concentrations of 0.1, 1 and 10 percents. There was no inhibition.

ESH Observations. Only two concentrations were tested, 1 and 2.5 percents. Both of these allowed 100 percent decay.

Phygon Paste

Active Ingredient. 55 percent 2,3 dichloro 1,4 naphthquinone.

Producer. Naugatuck Chemical Div., U. S. Rubber Company.

Chemical and Physical Data. A yellow-brown paste that forms a suspension when mixed with water. There is an "absence of toxic effects from prolonged contact with the body surface." It is practically nontoxic to animals and human beings. Concentrated powder on freely perspiring persons may cause skin to redden. (See Phygon XL.) Specific oral toxicological data were not available.

Fungicidal Efficiency. It has been found to be an extremely potent fungicide and has been rated as an AAA compound, which means it must have an LD_{50} of 0.1 - 0.01 ppm. Phygon has an LD_{50} of 0.03 ppm.

Laboratory Observations, Plate I, Fig. 2 and Plate III, Fig. 60. All concentrations obviously suppressed the overall growth of the fungus. The medium concentration was most effective. Decay of plugs was retarded until after 36 hours. Sporulation was inhibited in the immediate vicinity of the fungicide in all concentrations, but just beyond this area there was stimulated sporulation. Beyond these concentric rings the fungus characteristics were comparable with the untreated check plates.

ESH Observations. Phygon Paste, at concentrations of 30 grams per 4 liters water (about 1 oz./gal. or 0.75 percent conc.) or greater, seriously injured the skin of the roots along the cut surface. It always formed a thick, dark crusty wound cork and permitted an average, in all concentrations, of about one-third decay. Decay actually varied from 20 percent to 80 percent. All concentrations above 0.7 percent permitted relatively the same amount of decay, about 35 percent.

Phygon XL - MS

Active Ingredient. 50 percent 2,3 dichloro 1,4 naphthquinone, and 50 percent magnesium sulfate.

Producer. Naugatuck Chemicals Div., U. S. Rubber Company.

Chemical and Physical Data. A dark yellow very finely ground dust that suspends readily in water. Needs no wetting agent. Toxicity tests made with laboratory animals have shown that Phygon is one of the safer fungicides to use. In order to kill 50 percent of the albino test rats, approximately 2.5 grams of active ingredient had to be fed per kilogram body weight.

Fungicidal Efficiency. As little as four parts per 100 million parts of water will prevent the germination of spores of the plant disease fungi *Alternaria* and *Sclerotinia*. (This probably refers to 100 percent of the active material.) Used to control apple scab, black rot and bitter rot of apples, bean anthracnose, cherry leaf spot, brown rot of stone fruits, celery blight, early and late leaf blight of tomatoes. Also used as seed protectant.

Laboratory Observations, Plate I, Fig. 3 and Plate III, Fig. 56. This fungicide has shown to be the most effective when used with the paper discs. The regions of inhibition are distinct and seem to be the most pronounced in the medium concentration, but more effective in the low concentration than in the high. Around the sweetpotato plugs, the best inhibition was in the highest concentration, the least in the lowest. All plugs decayed within 24 hours. Note the intensity of sporulation around the paper discs in Figs. 3 and 56; this is comparable with Phygon Paste, Fig. 2.

ESH Observations. Phygon XL, in general, showed somewhat better protection of the sweetpotato plugs than Phygon Paste but the amount of decay was more variable. It also injured the skin along the cut surface but not so seriously as Phygon Paste. Best protection is probably at a concentration greater than 1 percent. Erratic results might be attributed to the magnesium sulfate.

Parzate, liquid

Active Ingredient. Sodium salt of ethylene bis dithiocarbamic acid.

Producer. Grasselli Chemicals Department, E. I. duPont de Nemours and Co.

Chemical and Physical Data. The salt is soluble in water up to about 30 percent. The solution supplied by the company was an orange liquid having recommended use-dilutions at not more than 1 quart per 100 gallons water.

Fungicidal Efficiency. Not specified by the producer but this material has been used on "foliage and limited tests with post-harvest-treated peaches."

Laboratory Observations, Plate II, Fig. 33, and Plate III, Fig. 51. Parzate liquid has shown to be effective in the inhibition of *Rhizopus nigricans* in concentrations of 20 percent or better. There is definite evidence of inhibition in concentrations of 20, 30, 40 percent and no inhibition in concentrations of 0.1, 1 and 10 percents. The mycelia grows and sporulates well everywhere except in the immediate proximity of the higher concentrations. At the very high concentrations the active ingredient either stained or caused coagulation of the agar (Fig. 51). All the plugs decayed, either from the fungus or because of chemical injury.

ESH Observations. Because the laboratory observations produced no encouraging results, Parzate liquid was used at a concentration of 5 percent only. This gave 100 percent decay.

Parzate, calcium

Active Ingredient. Calcium salt of ethylene bis dithiocarbamic acid.

Producer. Grasselli Chemicals Department, E. I. du Pont de Nemours and Co.

Chemical and Physical Data. The salt is soluble in water up to about 30 percent. The solution supplied by the company was a reddish liquid. The recommended use-dilutions were suggested at not more than 1 quart per 100 gallons water.

Fungicidal Efficiency. Not definitely known, see Parzate, liquid.

Laboratory Observations, Plate II, Fig. 34; Plate III, Fig. 52. This material has responded quite similarly to Parzate, liquid, but shows evidences of being slightly more inhibitive to the fungus. General inhibition patterns conform to that of the sodium salt. All plugs decayed before 72 hours either from infections of the fungus or chemical injury causing a breakdown.

ESH Observations. Parzate, calcium, was used only at 5 percent concentration. This allowed 93 percent decay.

Parzate, magnesium

Active Ingredient. Magnesium salt of ethylene bis dithiocarbamic acid.

Producer. Grasselli Chemicals Department, E. I. du Pont de Nemours and Co.

Chemical and Physical Data. A dark-red liquid was supplied by the company and is said to be about a 30 percent solution of the active ingredient. Use-dilutions were recommended at not more than 1 quart per 100 gallons water.

Fungicidal Efficiency. Not definitely known; probably about the same as for the sodium and calcium salts.

Laboratory Observations, Plate II, Fig. 35; Plate III, Fig. 53. Areas of inhibition conform very closely to the other Parzate salts. No unusual differences were noted.

ESH Observations. A 5 percent concentration was the only one used. This allowed 100 percent decay.

Parzate, zinc dust

Active Ingredient. Zinc salt of ethylene bis dithiocarbamic acid.

Producer Grasselli Chemicals Department, E. I. du Pont de Nemours and Co.

Chemical and Physical Data. This light brown-gray powder is generally accepted, since it is a zinc containing compound, to be not suitable for human consumption. Its recommended use was restricted at concentrations greater than 0.25 percent.

Fungicidal Efficiency. Not definitely known; information supplied by the company referred to foliage tests and fresh peach investigations.

Laboratory Observations, Plate II, Fig. 36. This zinc salt showed greater effectiveness than either the sodium, calcium or magnesium salts. The area of inhibition around the high concentration was clear and distinct, however, small. Sporulation was reduced about the high concentration. The growth of the mycelia seemed to be encouraged at the high concentration. All the plugs were infected and decayed at 36 hours. A check plate with 5 percent as the high concentration was intermediate between the 1 percent and 10 percent areas of the original plate.

ESH Observations. Parzate, zinc dust, was more effective than other Parzates. Chemical injury was evident by the "burned" areas on the skin of the roots. A single concentration was used (5 percent) and 89 percent decay resulted.

Dithane Z-78

Active Ingredient. Zinc ethylene bisdithiocarbamate.

Producer. Rohm & Haas Company.

Chemical and Physical Data. See Parzate, dust.

Fungicidal Efficiency. In unpublished results, this material has caused severe "burning" of the skin of the sweetpotatoes. This injury has resulted in easy soft rot infection.

Laboratory Observations, Plate II, Fig. 37; Plate III, Fig. 58. As a compound in which the active ingredient is the same as that found in Parzate, dust, Dithane Z-78 gave an entirely different picture in these observations. The mycelia grew more luxuriantly, infection of the plugs was more rapidly and sporulation of the fungus seemed to be more profuse. This is evident by the dark rings around the paper discs (Fig. 37). The concentrations of active ingredient were lower than those in Fig. 36, except for the lowest concentration, but this did not in any way reflect the similarity of the fungicidal properties.

ESH Observations. There is no conclusive information as to the effectiveness of Dithane in the control of Rhizopus nigricans as far as this investigation is concerned. The percentage of decay varied as widely as the concentrations that were used. There was some "burning" of the skin in all but the 0.5 percent concentration. These chemically injured areas could easily have promoted the amount of decay. The concentration where this injury was not serious (0.5 percent) was also the concentration of least decay.

C. P. 546

Active Ingredient. Zinc ethylene bis (N-2-cyanoethyldithiocarbamate).

Producer. Monsanto Chemical Company.

Chemical and Physical Data. A white granular material that suspends easily in water. The use-dilutions were recommended at 1 pound per 100 gallons water. At this concentration there is a relatively low order of toxicity to warm blooded animals.

Fungicidal Efficiency. Not definitely known.

Laboratory Observations, Plate III, Fig. 42. There were small areas of inhibition in the medium and the high concentration areas at 36 hours incubation but shortly after, the fungus grew luxuriantly over the plugs infecting them and causing decay.

ESH Observations. There was 100 percent decay at 1 percent concentration.

Experimental Fungicide 5379

Active Ingredient. ". . .the reaction product of sulfur dichloride and disodium ethylene bis dithiocarbamate."

Producer Carbide and Carbon Chemicals Corporation.

Chemical and Physical Data. A light yellow dust that suspends easily in water. Toxicological data not available.

Fungicidal Efficiency. Not known.

Laboratory Observations, Plate I, Fig. 16. Inhibition in the medium and high concentrations. The growth of the mycelium seems to be considerably stimulated adjacent to the areas of inhibition. Plugs all decayed within the third day.

ESH Observations. Nearly 100 percent decay in concentrations of 1 percent and 2.5 percent.

Zerlate

Active Ingredient. 70 percent zinc dimethyl dithiocarbamate.

Producer. E. I. du Pont de Nemours, Inc.

Chemical and Physical Data. A white granular powder that suspends readily in water. Toxicological data not supplied by the producer. Compounds containing zinc are generally considered not suitable for human consumption.

Fungicidal Efficiency. Has been used extensively in experimentations without significant conclusive results.

Laboratory Observations, Plate I, Fig. 9. Inhibition of mycelia is pronounced especially at 0.5 percent. Mycelial growth was luxuriant, except in the low concentration where sporulation was very much reduced. Plugs all decayed within 72 hours.

ESH Observations. As the concentration of the fungicide was increased the amount of decay decreased. At 1 percent concentration the amount of decay was an average of about 33 percent.

Fermate

Active Ingredient. 70 percent ferric dimethyl dithiocarbamate.

Producer. E. I. du Pont de Nemours, Inc.

Chemical and Physical Data. A fluffy black powder of very small particle size that is relatively hard to wet. Fermate is irritating to mucous membranes; complete toxicological data were not obtained.

Fungicidal Efficiency. Fermate is highly effective against many fungi on apples, pears, cherries, beans, celery, cranberries, tomatoes, tobacco and others.

Laboratory Observations, Plate I, Fig. 10 and Plate III, Fig. 55. Outstanding areas of inhibition were present. Sweetpotato plugs decayed after 36 hours at 0.1 and 0.5 percent concentrations, but did not decay at any time at the 1 percent concentration.

ESH Observations. The refrigerating unit broke down in the first experiment allowing the temperature to get above 85° F. This increased the healing of the sweetpotato pieces and the amount of decay was reduced. Valid tests indicate that Fermate does not materially inhibit the fungus. Decay at 0.5 percent concentration was 90 percent; at 1 percent concentration, 95 percent decay.

Vancide 51

Active Ingredient. Sodium salts of dimethyl dithiocarbamic acid and 2-mercaptobenzothiazole.

Producer. R. T. Vanderbilt Company.

Chemical and Physical Data. A yellow brown liquid that is soluble in water in all proportions. It is nontoxic to warm-blooded animals; is not a sensitizer or primary irritant when in contact with the human skin.

Fungicidal Efficiency. *Aspergillus niger* is killed at 0.005 percent. This fungicide is used to protect freshly sawed lumber from organisms causing sap stain.

Laboratory Observations, Plate II, Fig. 21. Tested *in vitro* the areas of inhibition were excellent. Sporulation of the fungus was reduced over the entire plate. The mycelium, however, grew over the plate after 72 hours, still leaving the well-defined areas of inhibition but infecting all sweetpotato plugs causing decay.

ESH Observations. As the concentration of the fungicide increased the amount of decay decreased. Using 250 sweetpotatoes and 1 percent concentration, all the pieces decayed on one set of tests. On another set of tests, however, the same concentration allowed 38 percent decay. The action of Vancide 51 on the wounded surface, after two weeks, was very favorable. There was no thick, dark, crusty, wound-cork formation, but rather, a light surface that had all the characteristics of having just been cut.

Vancide 32

Active Ingredient. The beta-hydroxy ethyl pyridinium salt of 2-mercapto benzothiazole.

Producer. R. T. Vanderbilt Company.

Chemical and Physical Data. A reddish colored liquid that is very soluble in water. It is nontoxic to warm-blooded animals and is not a sensitizer or primary irritant when in contact with human skin.

Fungicidal Efficiency. Lethal for *Aspergillus niger* at 0.02 percent and *Penicillium* spp. at 0.01 percent *in vitro*.

Laboratory Observations, Plate II, Fig. 22. The mycelial growth was inhibited partially at 1 percent and completely at 10 percent. When assayed at 5 percent the effect was intermediate between 1 percent and 10 percent. In all cases sweetpotato plugs decayed but there was evidence of chemical injury causing the decay at 10 percent concentration.

ESH Observations. Vancide 32 allowed consistent and definite increase in the percentage of rot as the concentration decreased. There was no evidence of chemical injury at 5 percent. *Penicillium* spp. was not observed at 1 percent or 5 percent. The decay at 1 percent concentration was 91 percent.

Vancide 48

Active Ingredient. Lauryl pyridinium and sodium salts of 2 mercapto-benzothiazole.

Producer. R. T. Vanderbilt Company.

Chemical and Physical Data. It is a yellow-brown liquid, which, when added to water forms stable colloidal suspensions. It is nontoxic to warm-blooded animals; and is not a sensitizer or primary irritant when in contact with human skin.

Fungicidal Efficiency. *Aspergillus niger*, *in vitro*, is killed at 0.002 percent. Effective in the protection of cellulose materials in the range of 0.05 to 0.2 percent against *Chaetomium globosum*, *Metarrhizium glutinosum*, *Penicillium* spp., and *Trichoderma* T-1.

Laboratory Observations, Plate II, Fig. 23. Mycelial growth was reduced at 1 percent and very much reduced at 10 percent. Sporulation was reduced likewise. Sweetpotato plugs were decayed at 0.1 percent and at 1 percent but did not rot at 10 percent until about 72 hours. A check plate using 5 percent in the high concentration was intermediate between 1 percent and 10 percent; results were the same.

ESH Observations. Vancide 48 allowed an increase in the amount of rot as the concentration decreased. In lower concentration, 0.1 percent and 1 percent, it was a little better than Vancide 32 but not so good as Vancide 51. No *Penicillium* was noticed and *Rhizopus* grew luxuriantly. At 1 percent concentration there was 78 percent decay.

Vancide 21

Active Ingredient. Cetyl amine salt of 2-mercaptobenzothiazole.

Producer. R. T. Vanderbilt Company.

Chemical and Physical Data. A yellow to brown solid that is insoluble in water as such, but it has been made into a liquid form that mixes readily with water. It is nontoxic to warm-blooded animals and is not a sensitizer or primary irritant when in contact with the human skin.

Fungicidal Efficiency. *In vitro*, *Aspergillus niger* and other textile destroying fungi were killed in ranges from 0.01 percent to 0.005 percent.

Laboratory Observations, Plate II, Fig. 24. Mycelial growth was inhibited at 10 percent only, but over-all growth was reduced in the medium and high concentrations. Sweetpotato plugs decayed at all concentrations tested.

ESH Observations. Vancide 21 gave inhibition only at the high concentration (10 percent) in the laboratory. An exploratory test was made here using a 5 percent solution. This produced 100 percent decay. It was the only concentration tested.

Vancide 26 EC

Active Ingredient. Lauryl pyridinium salt of 5-chloro- 2-mercaptobenzothiazole.

Producer. R. T. Vanderbilt Company.

Chemical and Physical Data. A dark colored liquid, which when added to water forms stable dispersions. It is nontoxic to warm-blooded animals and is not a sensitizer or primary irritant when in contact with human skin.

Fungicidal Efficiency. *In vitro*, *Penicillium* spp. and other textile and cellulose destroyers killed at ranges from 0.005 percent to 0.02 percent (by weight).

Laboratory Observations, Plate II, Fig. 26. Mycelial growth and the sporulation of the hyphae was reduced at 10 percent only. The mold covered the entire plate, growing over the sweetpotato plugs at all concentrations. Plugs decayed at 0.1 percent and 1 percent but did not rot at 10 percent even after 72 hours. When checked at 5 percent after 52 hours, the plugs had decayed on one plate but not on the other.

ESH Observations. Vancide 26 EC was checked at an exploratory concentration of 5 percent. In the two tests the decay was 59 percent in the one soil bucket and 61 percent in the other. No additional tests were made.

Vancide 20S

Active Ingredient. Monoethanol ammonium salt of 2 mercaptobenzothiazole.

Producer. R. T. Vanderbilt Company.

Chemical and Physical Data. A dark red colored liquid, which, when added to water, would give a 5 percent solution; higher percentages show increasing turbidity. It is nontoxic to warm-blooded animals and is not a sensitizer or primary irritant when in contact with human skin.

Fungicidal Efficiency. *In vitro*, *Penicillium* spp. and other textile and cellulose destroyers were killed at concentrations ranging from 0.01 percent 0.005 percent (by weight).

Laboratory Observations, Plate II, Fig. 25. Mycelial growth was reduced at 1 percent especially at the paper disc and was considerably reduced at both the plug and disc at 10 percent. All sweetpotato plugs were decayed after 72 hours.

ESH Observations. Only one concentration, 2½ percent, was used. At this concentration Vancide 20S permitted 100 percent decay.

Tetrosan 60 Percent

Active Ingredient. Alkyl (C_8H_{17} to $C_{18}H_{37}$) dimethyl 3,4-dichloro benzyl ammonium chlorides and alkenyl (C_{16} to C_{20}) dimethyl ethyl ammonium bromides in the ratio of 5:1, respectively.

Producer. Onyx Oil and Chemical Company.

Chemical and Physical Data. A clear, mobile liquid, light yellow to amber. It has a mild characteristic odor and a bitter taste. Use-dilutions are colorless and virtually without taste. It is miscible in any proportion with water. It is nontoxic to warm-blooded animals at concentrations less than 0.1 percent. Normal human skin is neither irritated nor sensitized by concentrations of 0.1 percent or less.

Fungicidal Efficiency. Not known definitely; it has been used extensively against bacteria and is effective for certain purposes.

Laboratory Observations, Plate II, Fig. 28. The growth of the mycelia was abundant, especially at 0.1 percent and 1 percent. Very small area of inhibition at 10 percent but all sweetpotato plugs were decayed after 45 hours.

ESH Observations. The amount of decay increased as the concentration decreased. At the best usable concentration, 1 percent, there was 85 percent decay.

Onyxide 75 Percent

Active Ingredient. Mixture of alkenyl dimethyl ethyl ammonium bromides in which the predominating alkenyl radical contains 18 carbon atoms.

Producer. Onyx Oil and Chemical Company.

Chemical and Physical Data. A tan paste of pleasant characteristic odor but bitter in taste. Soluble in, and at high dilutions (1:1000) reduces surface tension of water. Use-dilutions of Onyxide are apparently nontoxic to warm-blooded animals. Higher concentrations, however, may be considered irritating. Use-dilutions higher than 1:1000 are not irritating to normal human skin, nor do such concentrations sensitize.

Fungicidal Efficiency. Not definitely known. This material is used extensively as a bacteriacide in dilutions of 1:300 on eating utensils and food handling equipment.

Laboratory Observations, Plate II, Fig. 29. Very slight inhibition present only at 10 percent concentration. Sweetpotato plugs all decayed within 72 hours.

ESH Observations. The percent of decay increased as the concentration decreased. At 0.5 percent (effective against bacteria) there was 96 percent decay.

BTC

Active Ingredient. Alkyl (C_8H_{17} to $C_{18}H_{37}$) dimethyl benzyl ammonium chloride.

Producer. Onyx Oil and Chemical Company.

Chemical and Physical Data. BTC is water white; has a pleasant but very slight odor, and tastes bitter in concentrated solutions. It is relatively nontoxic at usable dilutions to man and is also nonirritating to the skin at 0.1 percent concentration within 5 days after exposure. The recommended basic dilution for BTC is 1:5000 of active material.

Fungicidal Efficiency. Not known fully; BTC is widely used against bacteria for numerous antiseptic practices. Also used to control slime and algae in water reservoirs.

Laboratory Observations, Plate II, Fig. 30. There was an abundant mycelial growth in the low concentration, 0.1 percent, this diminished in the medium and high concentration areas. Inhibition was very slight around the 10 percent area. All the sweetpotato plugs had decayed after 72 hours, the plug at 10 percent being the last, starting at about 45 hours.

ESH Observations. Expectations of increased rot as the concentration decreased resulted. The low concentration, 0.5 percent is very high compared to the recommended basic dilution and even the 73 percent decay that was present would suggest its inefficiency.

L - 7752

Active Ingredient. ". . . quarternary ammonium compound."

Producer. Standard Oil Company of Indiana.

Chemical and Physical Data. Not supplied by the company.

Fungicidal Efficiency. Not known. This material has been used in investigations on apple scab and peach brown rot.

Laboratory Observations, Plate II, Fig. 31. Inhibition only around the paper disc at 10 percent. Mycelial growth abundant, infecting all sweet-potato plugs producing decay.

ESH Observations. Tested at only one high concentration, 5 percent, there was 52 percent decay.

L - 7187

Active Ingredient. ". . . quarternary ammonium compound."

Producer. Standard Oil Company of Indiana.

Chemical and Physical Data. Same as for L - 7752; a clear oily liquid.

Fungicidal Efficiency. Not supplied by the producer. In general, quarternary ammonium compounds are more specific for bacteria.

Laboratory Observations, Plate II, Fig. 32. Luxuriant mycelial growth was present. There was no inhibition and all the plugs were decayed.

ESH Observations. Only one high concentration was tested, 5 percent. This allowed 80 percent decay. Whether or not L-7187 and L-7752 chemically injured the roots was not ascertained. Comparing these quaternary ammonium compounds with others, Onyxide, Tetrosan, BTC, chemical injury is doubtful inasmuch as inhibition would normally be present before such a concentration would cause chemical injury.

Acti-dione

Active Ingredient. Cycloheximide, beta-[2-(3,5 -dimethyl - 2 - oxo-cyclohexyl)- 2 - hydroxethyl] glutarimide, 25 mg in isopropanol.

Producer. The Upjohn Company.

Chemical and Physical Data. A brown oily liquid that is an antibiotic from *Streptomyces griseus*. Exhibits phytotoxicity at very low concentrations. It is not recommended for human consumption at any concentration.

Fungicidal Efficiency. Active as low as 1 ppm. Shows promise on turf diseases, mildews of strawberries, cucumber scab and brown rot of peaches.

Laboratory Observations, Plate I, Fig. 17. Reduced mycelial growth over the entire plate. Inhibition in the high concentration (10 percent) only. All plugs decayed at 48 hours (see DISCUSSION of Acti-dione) in one set of tests. In two other sets of tests, only the plugs in the low concentration were dedayed.

ESH Observations. Acti-dione gave the best over-all results of any one fungicide. The greatest amount of decay was 26 percent at a concentration of 0.25 percent. As the concentration of the fungicide increased, the amount of decay decreased. A secondary fungus *Penicillium* was abundant at 0.25, 0.5, and 1 percents but was absent at 2.5 percent concentrations.

CRAG Fruit Fungicide

Active Ingredient. 50 percent isopropanol and 50 percent mixture of 2-heptadecyl glyco-oxalidine (65 percent); 2-pentadecyl glyco-oxalidine (32 percent); and heptadecenyl glyco-oxalidine (less than 3 percent).

Producer. Carbide and Carbon Chemical Corporation.

Chemical and Physical Data. A dark brown oily liquid that mixes well with water. This complex mixture contains materials that are in themselves fungicides. Toxicological properties were not supplied by the producer.

Fungicidal Efficiency. This material has been effective in apple scab control, snap dragon rust and cherry leaf spot.

Laboratory Observations, Plate III, Fig. 47 and 48. There was vigorous and abundant mycelial growth over the entire plate in all concentrations of the fungicide tested. All the plugs decayed. Note the chemical stain around the paper discs in Fig. 48.

ESH Observations. As the concentration of the fungicide increased the amount of decay decreased. A 1 percent solution allowed 72 percent decay.

Goodrite Latex, VL - 600

Active Ingredient. 54 percent vinal - chlorite latex.

Producer. B. F. Goodrich Chemical Company.

Chemical and Physical Data. A white milky liquid that provides a continuous film over the entire surface of the dipped materials. There are no toxic problems involved and the material can be eaten up to indeterminate amounts. It has no fungicidal properties but will not permit strictly aerobic fungi to grow well under anaerobic conditions beneath the rubbery film.

Fungicidal Efficiency. This material is being used exclusively for the prevention of stalk rot of bananas during shipment.

Laboratory Observations, Plate II, Fig. 38. At 36 hours the mycelia were unable to infect the sweetpotato plugs but the plugs were beginning to decay from within. The apparent areas of inhibition are merely areas of reduced sporulation. The density of the fungus in the high concentration area is due to a more dense agar medium in this particular plate. At 72 hours all plugs were decayed.

ESH Observations. All sweetpotato pieces decayed from within. There was no shriveling or drying of the decayed pieces. Ten whole sweetpotatoes were dipped in a 50 percent (volume) of the prepared Latex in November, 1949. On two of these roots, the tips were trimmed off in under the solution; the other eight were trimmed before the dip. The latter eight roots decayed within 5 days. The former two roots were left exposed to the warmth of the laboratory for over 5 months. There was no decay, neither were the roots seriously shrivelled, nor were they discolored.

Peps

Active Ingredient. 80 percent polyethylene polysulfide.

Producer. B. F. Goodrich Chemical Company.

Chemical and Physical Data. A nontoxic yellow-brown clay-like material that produces a discontinuous film on a surface but has an objectionable sulfur like odor.

Fungicidal Efficiency. It is used to control apple scab, cedar apple rust on apples, grape black rot, peach brown rot, cherry leaf spot, raspberry anthracnose. Its most important use is an adhesive for other fungicides.

Laboratory Observations, Plate I, Fig. 18 and Plate II, Fig. 40. Inhibition and protection only around the 5 percent concentration area. The plugs did not decay during the entire time of exposure to the fungus. Areas of inhibition were generally small.

ESH Observations. The amount of decay increased as the concentration of Peps decreased. At 5 percent concentration, the best lab results, there was 59 percent decay.

Experimental Fungicide 974

Active Ingredient. ". . . a sulfur containing organic."

Producer. Carbide and Carbon Chemical Corporation.

Chemical and Physical Data. This is a white crystalline solid, soluble in water up to 0.12 percent and in acetone up to 19.4 percent by weight. It has very little odor. At concentrations preventing fungous growth (15 ppm) there is no primary skin irritation or dermatitis on human skin. Low concentrations are hazardous on ingestion.

Fungicidal Efficiency. Concentrations of 15 ppm prevented growth of *Aspergillus*, *Penicillium*, *Chaetomium*, *Curvularia* and *Memnoniella*, *in vitro*.

Laboratory Observations, Plate III, Figs. 49 and 54. There was abundant and luxuriously growing mycelia growing over the entire plate. Sporulation was inhibited around the paper discs (Fig. 54). All the plugs decayed within 3 days.

ESH Observations. Only one concentration was tested, 5 percent; this allowed 100 percent decay in both the test samples.

Sulfur, Wettable and Dusting

Active Ingredient. Elemental sulfur.

Producer. Some unlabeled laboratory stock was used.

Chemical and Physical Data. Elemental sulfur is commonly used as yellow "flowers of sulfur." Both the wettable and the dusting sulfur possess, for all practical purposes, the same fungicidal properties. Sulfur by itself is not considered to be an extremely active fungicide, at least not so active as it may be when it is used in combination with other materials such as lime or in some organic form.

Fungicidal Efficiency. The toxicity of sulfur to conidia of *Sclerotinia americana* is a function of the fineness of the particles (Frear (5)).

Laboratory Observations, Plate III, Fig. 44. Sulfur is somewhat active in reducing the mycelial growth over the entire plate. The plugs all decayed.

ESH Observations. Sulfur was used only at one concentration, because of the poor laboratory response. At 0.7 percent (by weight) sulfur allowed 65 percent decay.

CRAG Potato Fungicide

Active Ingredient. Copper-zinc-chromate.

Producer. Carbide and Carbon Chemicals Corporation.

Chemical and Physical Data. A light green powder that suspends easily in water. Toxicological data were not supplied by the producer. This material is probably not suitable for human consumption.

Fungicidal Efficiency. Data not available.

Laboratory Observations, Plate I, Fig. 14. There was good inhibition in the medium and high concentrations. After 3 days all the plugs decayed.

ESH Observations. 100 percent decay in both concentrations tested, 1 percent and 2.5 percent.

Borax

Active Ingredient. Sodium tetraborate.

Producer. Pacific Coast Borax Company.

Chemical and Physical Data. The white granular powder that is used in the home for washing purposes. The Pure Food and Drug Law has prohibited the use of Borax for human consumption.

Fungicidal Efficiency. Not fully known. Daines (3) and Parris (17) have found Borax useful in soft rot control.

Laboratory Observations. Plate I, Fig. 15. Good inhibition at high concentrations (5 percent); no inhibition at the medium or low concentrations. Plugs decayed at 0.1 and 1 percents. Plug at 5 percent protected but chemically injured.

ESH Observations. As the concentration of Borax increased the amount of decay decreased. At concentrations of 2 percent and at 2.5 percent, there was 43 and 44 percent decay, respectively.

Mycoban

Active Ingredient. Sodium propionate.

Producer. E. I. du Pont de Nemours, Inc.

Chemical and Physical Data. Mycoban is a white granular powder giving a clear colorless solution in water.

Fungicidal Efficiency. Mycoban is used extensively in the baking industry, especially during the summer months, for the inhibition of bread molds. A concentration of about ½ pound per 300-350 pounds of dough is used.

Laboratory Observations, Plate III, Fig. 43. Mycoban actually stimulated sporulation in *Rhizopus nigricans*. An abundant mycelial growth covered each plug causing decay.

ESH Observations. Nearly 100 percent decay resulted in all concentrations tested from 0.25 to 2.2 percents.

Urea

Active Ingredient. Urea.

Producer. Laboratory stock.

Chemical and Physical Data. White crystalline salt slightly soluble in water.

Fungicidal Efficiency. Not known.

Laboratory Observations. No laboratory observations were made.

ESH Observations. Only one test was made. This was in the commercial storage house itself. Decay was 100 percent for 0.5 percent concentration. It was decided that Urea was primarily a bactericide and,therefore, it was not tested further.

DISCUSSION

Control of soft rot resolves itself into two distinct problems: first, prevention during the storage period; and secondly, control between the time of removal of the sweetpotato from storage and the time of consumption.

Soft Rot Prevention During the Storage Period

Weimer and Harter (23) and other workers have shown quite definitely that the chances of infection of injured sweetpotatoes with storage rots are very largely dependent on the presence or absence of the wound-cork layer and on the temperatures that delay or promote wound-cork formation.

The normal skin of the sweetpotato consists of a thin layer of dry, thin-walled, corky cells that resist water loss as well as the entrance of decay producing microorganisms. The underlying tissue consists chiefly of large, thin-walled cells that are filled with starch grains and other food materials that are ideal for the growth of rot organisms.

When the skin of the sweetpotato is broken, a milky exudation occurs, which soon dries down. This is not true healing. The first step in the true healing process is a chemical change in the walls that have been exposed by the wounds. The wall of a few layers of cells becomes heavy and impervious and helps to prevent loss of moisture or entrance of disease spores. Under proper storage conditions this is followed by the production of new cells which develop a cork-like nature somewhat similar to the original skin of the sweetpotato and which permanently and effectively heal the wound.

Healing and the formation of wound-cork is stimulated by favorable temperatures and humidities. These true cork cells may not start to form for more than 10 days at the low humidity of 75 percent and at a temperature

of 75° F. Their formation may also be delayed at humidities as high as 92 or 93 percent if the temperature is as low as 65° F. These conditions were used in the ESH. No healing occurs at low temperatures or in dry air, therefore, the chances of infection under such conditions are greatly increased.

Experience has indicated that soft rot in the storage house is most serious when injury occurs from rough handling, especially during wet harvest weather. This is probably due to the wet soil clinging to the roots as they go into storage (17).

Soft Rot Prevention After the Storage Period

After the sweet potatoes leave the storage house there is no good method of preventing the infection of injured roots with the soft rot organism. Therefore, this investigation was undertaken to determine whether or not soft rot can be prevented thru the use of fungicidal protectants.

Results

Most of the fungicides used in the dip treatments included in this research were toxic above some concentration. Frequently this concentration offered good protection with very little decay from Rhizopus nigricans. This was true using the antibiotic, Acti-dione, and Dowcide F. Less effective were the Phygons, Sinox W and Dowcide A.

There was less decay in the ESH following the use of Acti-dione than with any other fungicide, at comparable concentrations.

In general, the volatile chlorinated phenols were the most effective fungicides tested for preventing soft rot. Other chlorinated phenols were less and some were not at all effective. Still other phenol containing

compounds were slightly, if at all, fungicidal.

The derivatives of 8-hydroxyquinoline were not effective fungicides. Copper-8-quinolinolate (Bioquin 1) protected the plugs in the laboratory, probably by stimulating healing in the presence of very high humidity within the petri dish. Such an environment was not found in the ESH.

Phygon (2,3 dichloro 1,4 naphthquinone) is the only fungicide used that has a low degree of toxicity and that shows promise for preventing soft rot.

Compounds containing derivatives of dithiocarbamic acid were not effective, at low concentrations, against Rhizopus nigricans.

A mixture of 2-mercaptobenzothiazol and a dithiocarbamic acid-derivative (Vancide 51) was a good inhibitor but did not effectively prevent decay. Other mercaptobenzothiazols were not very effective in either of the above.

The quarternary ammonium compounds were in general completely ineffective against Rhizopus nigricans.

The other organic compounds: glyco-oxalidines, sulfur containing materials, and urea, did not inhibit soft rot organisms.

Vinal-chlorite latex showed very good indications as a wax-substitute for sweetpotatoes. VL-600 is not a fungicide but it will prevent the growth of aerobic microorganisms beneath its continuous, glossy, water-resistant, rubbery surface. It is nontoxic to humans and can be eaten in large quantities.

Sodium propionate (Mycoban), a commercially recognized fungicide, was not effective against the black bread mold at any concentration tested.

Sodium tetraborate (Borax) inhibits Rhizopus nigricans but is not approved for use as a dip treatment by the Pure Food and Drug Administration.

Copper-zinc-chromate and elemental sulfur were not effective fungicides for the control of the soft rot organism.

Several significant factors have been discovered in this investigation even though the results have not yielded a fungicide that will completely prevent the infection of sweetpotatoes by *Rhizopus nigricans*.

Normally, sweetpotatoes do not suffer the wound-abuse that has been put to the pieces of roots involved in these tests. Neither would the optimum environmental conditions nor the amount of inoculum be so favorable for soft rot as occurred in the ESH as well as in the laboratory tests.

The correlation between the results of the preliminary laboratory investigations and those of the ESH were nearly identical except for Bioquin 1, which was previously explained, and Acti-dione. (This antibiotic deteriorates rapidly with age and warm temperatures. The solution used to make the concentrations for the photographs was at least six months old.)

A method of preliminarily evaluating a particular fungicide has been established. Through the use of this method many materials have been eliminated as being noneffective for controlling *Rhizopus nigricans* nor effective as protectants against soft rot in sweetpotatoes.

Two additional investigations remain before any fungicide can be recommended for commercial use:

1. An application of the materials under actual storage conditions. These conditions would, preferably, be at a time when harvest conditions are cold and wet.

2. That these materials used as dip treatments pass the requirements of the Pure Food and Drug Act.

SUMMARY AND CONCLUSIONS

1. In an attempt to check the growth of Rhizopus nigricans, a fungus causing soft rot in sweetpotatoes, 47 fungicides were applied to 419 experimental storage house tests involving over 21,000 pieces of sweetpotato roots.

2. A preliminary laboratory evaluation of the fungicides was made in order to determine a concentration of each fungicide at which the soft rot fungus itself is inhibited and also to find a concentration at which infection of sweetpotatoes is prevented.

3. Dip treatment with each fungicide in the experimental storage house tests (ESH) indicated:

a. Less than 5 percent decay of treated sweetpotatoes was present using Dowcide F and Acti-dione at concentrations of 1 percent or less.

b. Less than 20 percent decay was present using Phygon XL, Sinox W, Dowcide F, Dowcide A and Acti-dione at concentrations of 2½ percent or less.

c. All the materials that were recommended by their respective chemical companies as being nontoxic at use-dilutions allowed at least 50 percent or more decay of the pieces of sweetpotato roots. Phygon Paste and Phygon XL, which are practically nontoxic, averaged 35.27 percent decay for 36 tests using concentrations varying from 0.4-1.5 percent (by weight).

4. There is a correlation between the results of the preliminary laboratory evaluation of the fungicides and the results obtained from the treatment of sweetpotato roots in the experimental storage house. Any concentration that allowed decay in the laboratory nearly always allowed a high percentage of decay in the ESH.

5. Additional tests under the actual storage house conditions are yet necessary to supplement these findings.

ACKNOWLEDGMENT

In appreciation for the use of personal equipment, especially the commercial sweetpotato storage house during the fall, 1948; for supplying all the sweetpotatoes for this investigation; and for helpful suggestions and criticisms; the writer wishes to thank Dr. O. H. Elmer, major instructor, Department of Botany and Plant Pathology.

The writer also appreciates the useful information from Dr. Frank C. Gates and Travis E. Brooks, Dept. of Botany and Plant Pathology, and also from Dr. C. W. Colver, Russell Beers, and Robert Ziem, Dept. of Chemistry.

For her sincere patience and conscientious interest, Miss Nellie Jacobs, Clerk-Stenographer, Department of Botany and Plant Pathology, is hereby thanked most heartily for the excellant job of editing and typing this final copy of the thesis.

APPENDIX

Table 1. Farms reporting sweetpotatoes by acres harvested, 1939.

Acres harvested	Number of farms
- 5	1,148,579
5- 9	10,731
10-14	2,613
15-19	818
20-24	441
25-34	285
35-44	104
45-54	52
55-74	47
75-99	24
100 over	25

Table 2. Results of dip treatment for <u>Rhizopus</u> - soft rot control.

Materials used	Total treated	Number decayed	Percent of rot
Borax, 2# / 100 gal. water	3,713	16	0.44
Sulfur, 8#; oil; water to make 100 gal.	506	161	31.5
Sulfocide, 1 gal.; oil; water, 100 gal.	1,041	200	27.0
Untreated check.	878	436	50.0

Table 3. Fungicides that were tested (each insertion represents one group of tests); where each test was conducted; concentration of each fungicide used for each test; the number of tests that were treated for each concentration; the number of cut sweetpotato pieces in each test; and the percentage of decay after two weeks treatment.

CSH - commercial storage house.
ESH - experimental storage house
* - the refrigeration unit within the ESH failed to operate for 48 hours, thus, allowing the temperature to approach 85° F. These figures should be compared with 15 percent decay, instead of 100 percent decay, in the controls for these specific tests only.

Fungicide used	Where tested	Concentration percent		Number of tests	Number in tests	Percent decay
Dowcide F	ESH	0.5	(weight)	6	300	32
"	"	0.5	"	2	100	18
"	"	1	"	6	300	1.3
"	"	1	"	2	100	3
"	"	1	"	2	100	23
"	"	2.5	"	2	100	none
"	"	5	"	2	100	none
Phygon Paste	CSH	0.4	(weight)	2	40	80
" "	"	0.7	"	2	40	37
" "	"	0.8	"	2	40	35
" "	ESH	0.8	"	2	100	39
" "	"	1	"	2	100	36
" "	CSH	1.1	"	2	40	20
" "	ESH	1.1	"	2	100	44
" "	CSH	1.5	"	2	40	34
" "	ESH	1.5	"	2	100	36
Phygon XL-MS	CSH	0.7	(weight)	2	40	65
"	"	0.7	"	2	40	52
"	"	0.8	"	2	40	13
"	ESH	0.8	"	2	100	18
"	"	1	"	2	100	52
"	CSH	1.1	"	2	40	28
"	ESH	1.1	"	2	100	15
"	CSH	1.5	"	2	40	10
"	ESH	1.5	"	2	100	21
Sinox	ESH	0.5	(volume)	6	300	100
"	"	1	"	6	300	100
"	"	5	"	2	100	100
Sinox W	ESH	0.5	(volume)	2	100	47
"	"	1	"	2	100	15
"	"	1	"	2	100	18
"	"	5	"	2	100	100

Table 3. (cont.)

Fungicide used	Where tested	Concentration percent	Number of tests	Number in tests	Percent decay
Elgetol	ESH	1 (volume)	2	100	100
"	"	5 "	2	100	92
Bioquin	CSH	0.11 (weight)	2	40	75
"	"	0.11 "	2	40	60
"	"	0.11 "	2	40	70
"	ESH	0.11 "	2	100	3 *
"	CSH	0.17 "	2	40	55
"	ESH	0.17 "	2	100	14 *
"	CSH	0.22 "	2	40	92
"	ESH	0.22 "	2	100	12 *
"	"	0.5 "	2	100	66
"	"	1 "	2	100	51
Bioquin I	CSH	0.11 (weight)	2	40	73
"	"	0.11 "	2	40	33
"	"	0.11 "	2	40	35
"	ESH	0.11 "	2	100	48
"	CSH	0.17 "	2	40	5
"	ESH	0.17 "	2	100	27
"	CSH	0.22 "	2	40	10
"	ESH	0.22 "	2	100	32
"	"	0.5 "	2	100	67
"	"	1 "	2	100	49
Zerlate	ESH	0.5 (weight)	2	100	83
"	"	0.5 "	2	100	72
"	"	0.75 "	2	100	78
"	"	1 "	2	100	37
"	"	1 "	2	100	30
Fermate	CSH	0.27 (weight)	2	40	60
"	"	0.27 "	2	40	80
"	ESH	0.5 "	2	100	2 *
"	"	0.5 "	2	100	90
"	"	0.75 "	2	100	9 *
"	"	1 "	2	100	95
"	"	1 "	2	100	1 *
Bioquin 100	CSH	0.11 (weight)	2	40	73
"	"	0.11 "	2	40	74
"	"	0.11 "	2	40	60
"	ESH	0.11 "	2	100	9 *
"	CSH	0.17 "	2	40	62
"	ESH	0.17 "	2	100	14 *
"	CSH	0.22 "	2	40	32
"	ESH	0.22 "	2	100	3 *
"	"	0.5 "	2	100	63
"	"	1 "	2	100	77

Table 3. (cont.)

Fungicide used	Where tested	Concentration: Percent	Number of tests	Number in tests	Percent decay
Puratize - 177	ESH	0.5 (weight)	2	100	45
"	"	1 "	2	100	76
"	"	5 "	2	100	23
CRAG Potato Fungicide	ESH	1 (weight)	2	100	100
" " "	"	2.5 "	2	100	100
Borax	ESH	0.25(weight)	1	300	100
"	"	0.5 "	1	300	100
"	"	0.5 "	2	100	89
"	"	1 "	1	300	70
"	"	1 "	2	100	72
"	"	2 "	2	300	43
"	"	2.5 "	2	100	44
Experimental Fungicide 5379	ESH	1 (weight)	2	100	95
" " "	"	2.5 "	2	100	98
Acti-dione	ESH	0.25(volume)	1	300	26
"	"	0.5 "	1	300	18
"	"	0.5 "	2	100	1
"	"	1 "	1	300	19
"	"	1 "	2	100	16
"	"	1 "	2	100	4
"	"	2.5 "	2	100	10
Peps.	ESH	0.5 (weight)	2	100	100
"	"	1 "	2	100	92
"	"	5 "	2	100	59
Dowcide A	ESH	1 (weight)	2	100	61
"	"	2.5 "	2	100	19
"	"	5 "	2	100	none
Dowcide B	ESH	1 (weight)	2	100	77
"	"	2.5 "	2	100	58
"	"	5 "	2	100	none
Vancide 51	ESH	0.5 (volume)	5	250	100
"	"	0.5 "	2	100	88
"	"	1 "	5	250	100
"	"	1 "	2	100	38
"	"	5 "	2	100	38
Vancide 32	ESH	0.5 (volume)	2	100	100
"	"	1 "	2	100	91
"	"	5 "	2	100	49

Table 3. (cont.)

Fungicide used	Where tested	Concentration percent	Number of tests	Number in tests	Percent decay
Vancide 48	ESH	0.5 (volume)	2	100	90
"	"	1 "	2	100	78
"	"	5 "	2	100	58
Vancide 21	ESH	5 (volume)	2	100	100
Vancide 20 S	ESH	2.5 (volume)	2	100	100
Vancide 26 EC	ESH	5 (volume)	2	100	60
SCD - 765	ESH	0.1 (volume)	2	100	95
"	"	0.1 "	2	100	36 *
"	"	1 "	2	100	98
"	"	1 "	2	100	37 *
"	"	10 "	2	100	72
Tetrosan 60 percent	ESH	0.5 (volume)	2	100	96
"	"	1 "	2	100	85
"	"	5 "	2	100	28
Onyxide 75 percent	ESH	0.5 (volume)	2	100	97
"	"	1 "	2	100	93
"	"	5 "	2	100	38
BTC	ESH	0.5 (volume)	2	100	73
"	"	1 "	2	100	64
"	"	5 "	2	100	30
L - 7752	ESH	5 (volume)	2	100	52
L - 7187	ESH	5 (volume)	2	100	80
Parzate, liquid	ESH	5 (volume)	2	100	100
Parzate, calcium	ESH	5 (volume)	2	100	93
Parzate, magnesium	ESH	5 (volume)	2	100	100
Parzate, dust	ESH	5 (weight)	2	100	89
Dithane Z-78	ESH	0.5 (weight)	2	100	95
"	"	1 "	2	100	100
"	"	1 "	2	100	87
Goodrite Latex	ESH	5 (volume)	2	100	100
P. C. P.	ESH	1 (weight)	2	100	94
"	"	2.5 "	2	100	91

Table 3. (concl.)

Fungicide used	Where tested	Concentration percent	Number of tests	Number in tests	Percent decay
Peps.	ESH	0.5 (weight)	2	100	100
"	"	1 "	2	100	92
"	"	5 "	2	100	59
C. P. - 546	CSH	0.11 (weight)	2	40	58
"	"	0.11 "	2	40	70
"	"	0.17 "	2	40	70
"	"	0.22 "	2	40	58
"	ESH	1 "	2	100	100
Mycoban	CSH	0.25 (weight)	2	40	95
"	CSH	0.75 "	2	40	100
"	"	0.75 "	2	40	100
"	ESH	0.75 "	2	100	100
"	CSH	1.5 "	2	40	100
"	ESH	1.5 "	2	100	95
"	CSH	2.2 "	2	40	100
Sulfur, dusting	CSH	0.7 (weight)	2	40	42
" "	ESH	5 "	2	100	57
Sulfur, wettable	ESH	0.7 (weight)	2	100	65
G-4-40	ESH	0.1 (volume)	5	250	92
"	"	0.1 "	2	100	27 *
"	"	1 "	5	250	90
"	"	1 "	2	100	26 *
"	"	10 "	2	100	100
CRAG Fruit Fungicide	ESH	0.1 (volume)	2	100	76
" " "	"	1 "	2	100	72
" " "	"	10 "	2	100	39
Experimental Fungicide 974	ESH	5 (weight)	2	100	100
Seedox W	ESH	1 (weight)	2	100	88
"	"	5 "	2	100	100
8-hydroxyquinoline	ESH	1 (weight)	2	100	100
"	"	2.5 "	2	100	100
Urea	CSH	0.5 (weight)	2	40	100
Controls, UNTREATED.	CSH	————	12	480	av. 72
Controls, UNTREATED.	ESH	————	41	2050	av. 99.4

EXPLANATION OF PLATE I

Potato dextrose agar inoculated with *Rhizopus nigricans* on large (150 mm) petri dishes. Each dish represents the effects of one fungicide in three concentrations as indicated with filter paper discs (the lightest of adjacent circles) for each concentration and also with sweetpotato plugs (the darkest of adjacent circles) for each concentration. Photographs were made after 36 hours' incubation.

Legend for observations after 72 hours' incubation

(- inhibition around sweetpotato plug	H - high concentration, left third of dish
) - " " paper disc	M - medium conc., right third of dish
( ) - " " both plug and disc	L - low conc., lower third
___ - decayed plug	

Figures are given in percentages

	Percent	Percent	Percent	Percent
H -	(10)	(1.5)	(1.5)	(10)
M -	(1)	(1.1)	(1.1)	(1)
L -	.1	(.75)	(.75)	.1
	Figs. 1. Dowcide F	2. Phygon Paste	3. Phygon XL	4. Sinox

H -	(10)	(10)	(.22)	(.22
M -	(1)	1	(.17)	(.17
L -	.1	.1	.11)	(.11
	Figs. 5. Sinox W	6. Elgetol	7. Bioquin	8. Bioquin 1

H -	(.1	(1)	(1)	.22
M -	(.7	(.5)	(.5)	.17
L -	(.5	(.1)	.1)	.11
	Figs. 9. Zerlate	10. Fermate	11. Bioquin 100	12. Bioquin 100

H -	(.5)	(.5)	(5)	(.5)
M -	(1)	(1)	1	(1)
L -	.1	.1	.1	.1
	Figs. 13. Puratize	14. CRAG Fruit Fungicide	15. Borax	16. Experimental Fungicide 5379

H -	10)	(5	(10)	(10)
M -	1	1	(1)	1
L -	.1	.1	.1	.1
	Figs. 17. Acti-dione	18. Peps.	19. Dowcide A	20. Dowcide B

PLATE I


Fig. 1


Fig. 2

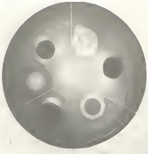
Fig. 3


Fig. 4


Fig. 5


Fig. 6

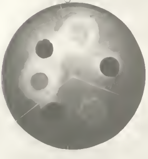
Fig. 7

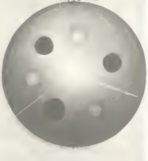
Fig. 8

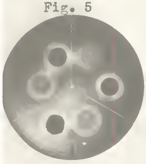
Fig. 9

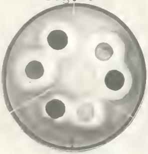
Fig. 10

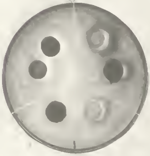
Fig. 11

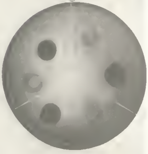
Fig. 12


Fig. 13

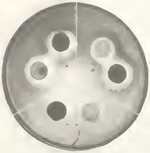
Fig. 14

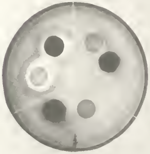
Fig. 15

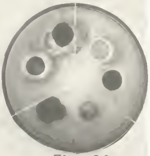
Fig. 16


Fig. 17


Fig. 18

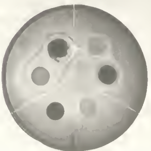
Fig. 19

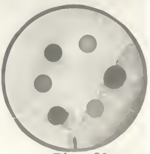
Fig. 20

EXPLANATION OF PLATE II

Potato dextrose agar inoculated with Rhizopus nigricans on large (150 mm) petri dishes. Each petri dish presents the effects of one fungicide in three concentrations as indicated with filter paper discs (the lightest of adjacent circles) for each concentration and also with sweetpotato plugs (the darkest of adjacent circles) for each concentration. In Figs. 36 & 38 only, the plugs are on the right of the discs. Photographs were made after 36 hours' incubation.

Legend for observations after 72 hours' incubation

(- inhibition around sweetpotato plug	H - high concentration, left third of dish
) - " " paper disc	M - medium concentration, right third of dish
( ) - " " both plug and disc	L - low concentration, lower third
___ - decayed sweetpotato plug	

Figures are given in percentages

	Percent	Percent	Percent	Percent
H -	($\underline{10}$)	($\underline{10}$)	($\underline{10}$)	($\underline{10}$)
M -	($\underline{1}$)	$\underline{1}$)	($\underline{1}$)	$\underline{1}$
L -	($\underline{.1}$)	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$

Figs. 21. Vancide 51 22. Vancide 32 23. Vancide 48 24. Vancide 21

H -	($\underline{10}$)	(10)	($\underline{10}$)	($\underline{10}$)
M -	$\underline{1}$)	$\underline{1}$	$\underline{1}$	$\underline{1}$
L -	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$

Figs. 25. Vancide 20S 26. Vancide 26 EC 27. SCD - 765 28. Tetrosan 60 percent

H -	($\underline{10}$)	($\underline{10}$)	$\underline{10}$)	$\underline{10}$
M -	$\underline{1}$	$\underline{1}$	$\underline{1}$	$\underline{1}$
L -	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$

Fig. 29. Onyxide 75% 30. BTC 31. L-7752 32. L-7187

H -	$\underline{10}$)	$\underline{10}$)	$\underline{10}$)	($\underline{10}$)
M -	$\underline{1}$	$\underline{1}$	$\underline{1}$	$\underline{1}$
L -	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$

Fig. 33. Parzate, Liq. 34. Parzate, Ca. 35. Parzate, Mg. 36. Parzate, dust

H -	$\underline{1}$	$\underline{10}$	$\underline{10}$	(5
M -	$\underline{.75}$	$\underline{1}$	$\underline{1}$	$\underline{1}$
L -	$\underline{.5}$	$\underline{.1}$	$\underline{.1}$	$\underline{.1}$

Fig. 37. Dithane - Z-78 38. Goodrite, Latex 39. P. C. P. 40. Peps

PLATE II


Fig. 21


Fig. 22


Fig. 23


Fig. 24


Fig. 25

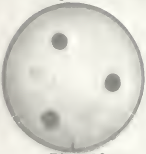
Fig. 26

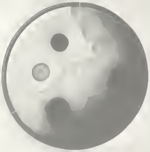
Fig. 27


Fig. 28

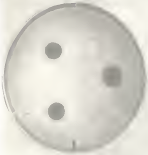
Fig. 29


Fig. 30

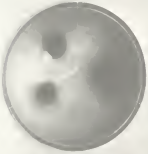
Fig. 31


Fig. 32


Fig. 33


Fig. 34

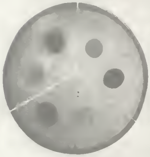
Fig. 35


Fig. 36


Fig. 37


Fig. 38


Fig. 39

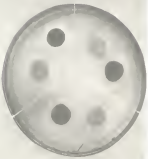
Fig. 40

EXPLANATION OF PLATE III

Potato dextrose agar inoculated with *Rhizopus nigricans* on large (150 mm) petri dishes. Each dish represents the effects of one fungicide in three concentrations as indicated with filter paper discs (the lighter of adjacent circles) for each concentration and also with sweetpotato plugs (the darkest of adjacent circles) for each concentration. Fig. 57 has the plug on the right of the disc, the others are on the left of the disc. Figs. 51 to 60 are duplicated fungicides showing additional concentrations. Figs. 41 to 56 were photographed after 36 hours' incubation; Figs 57 to 60 were photographed at 18 hours' incubation.

Legend for observations after 72 hours' incubation

(- inhibition around sweetpotato plug	H - high concentration, left third of dish
) - " " paper disc	M - medium conc., right third of dish.
( ) - " " both plug and disc	L - low conc., lower third
___ - decayed plug	

Figures are given in percentages

	Figs. 41. Bioquin 1	42. CP - 546	43. Mycoban	44. Sulfur
H -	(1)	(2.2)	2.2	10
M -	(.5)	1.7	1.5	1
L -	(.1)	1.1	.75	.1

	Figs. 45. G-4-40	46. G-4-40	47. CRAG Fruit Fungicide	48. CRAG Fruit Fungicide
H -	(10)	(40)	10	40
M -	(1)	(30)	1	30
L -	.1	(20)	.1	20

	Figs. 49. Experimental Fungicide 974	50. Seedox 50W	51. Parzate, liquid	52. Parzate, calcium
H -	10	10	(40)	(40)
M -	1	1	(30)	(30)
L -	.1	.1	(20)	(20)

	Figs. 53. Parzate, magnesium	54. Experimental Fungicide 974	55. Fermate	56. Phygon XL
H -	(40)	.3	(1)	(1)
M -	(30)	.2	(.7)	(.7)
L -	(20)	.1	(.5)	(.5)

Figs. 57. Puratize - 177 58. Dithane Z-78 59. Dowcide A 60. Phygon paste

PLATE III


Fig. 41


Fig. 42

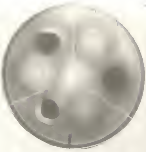
Fig. 43


Fig. 44

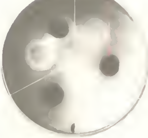
Fig. 45

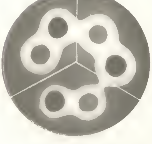
Fig. 46

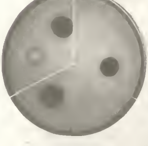
Fig. 47

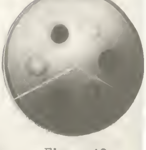
Fig. 48


Fig. 49


Fig. 50

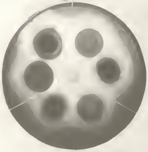
Fig. 51

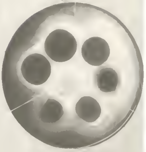
Fig. 52


Fig. 53


Fig. 54

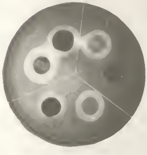
Fig. 55

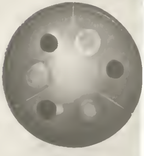
Fig. 56


Fig. 57


Fig. 58

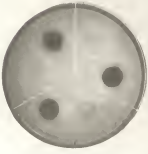
Fig. 59

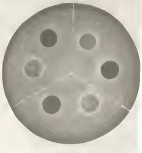
Fig. 60

Fig. 61. Sweetpotato production in the United States, 1866-1948. (13)

Fig.62. Annual soft rot losses (including other storage rots) in Kansas as compared to the United States, 1920 to 1949.

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